AIR WAR COLLEGE

AIR UNIVERSITY

EVOLVED EXPENDABLE LAUNCH VEHICLES (EELV)

FOR

OPERATIONALLY RESPONSIVE SPACE

By

Thomas M Steele, Lt Col, USAF

A Research Report Submitted to the Faculty

In Partial Fulfillment of the Graduation Requirements

12 February 2009

Report Documentation Page	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE	2. REPORT TYPE	3. DATES COVERED
FEB 2009	**N/A**	**-**

4. TITLE AND SUBTITLE	
Evolved Expendable Launch Vehicles (EELV) for Operationally Responsive Space	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **Air War College, Maxwell Air Force Base, Alabama**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR'S ACRONYM(S)
	11. SPONSOR/MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release, distribution unlimited

13. SUPPLEMENTARY NOTES
The original document contains color images.

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT	b. ABSTRACT	c. THIS PAGE			
unclassified	**unclassified**	**unclassified**	**SAR**	**35**	

DISCLAIMER

The views expressed in this academic research paper are those of the author and do not reflect the official policy or position of the US government or the Department of Defense. In accordance with Air Force Instruction 51-303, it is not copyrighted, but is the property of the United States government.

CONTENTS

ILLUSTRATIONS

BIOGRAPHY

Lt Col Steele was commissioned from Air Force Reserve Officer Training Corps (ROTC), Southern Illinois University Edwardsville in June 1987.

A Space and Missile Operations Officer, Lt Col Steele served operational tours at the 319^{th} Missile Squadron, 2^{nd} Space Launch Squadron (SLS), and the 576^{th} Flight Test Squadron. Lt Col Steele served on the Air Force Space Command Staff as Command Lead for the EELV program and at United States Strategic Command (USSTRATCOM) as Chief of Missile Strike Team. Additionally, he served another 2^{nd} SLS tour as the Operations Officer and Commanded the National Reconnaissance Office Launch Operations Squadron at Vandenberg AFB. He is now assigned to the Air War College at Maxwell AFB, Alabama.

Lt Col Steele has led several notable space launch operations campaigns. These include: The nations final flights of the Atlas E, Atlas IIAS, Titan II and Titan IV heritage boosters as well as the West Coast's first Delta IV and Atlas V EELVs.

Lt Col Steele has a Bachelors degree of Science and a Masters degree in Management. His personal awards include the Defense Meritorious Service Medal, Air Force Meritorious Service Medal, Air Force Commendation Medal and Air Force Achievement Medal. Lt Col Steele resides in Alabama while his wife and three children live in California.

INTRODUCTION

The Operationally Responsive Space (ORS) concept is important to military professionals seeking relevant and timely space capabilities. Over the last 10 years, the ORS concept has evolved from a responsive spacelift-only initiative towards a more comprehensive approach including responsive infrastructure, launch vehicles, satellites, and user systems. ORS has already energized emerging high tech companies such as Microsat, Microcosm, and SpaceX, who are ready to demonstrate cutting-edge, responsive space applications that can support national security needs. However, this enthusiasm regarding the ORS topic has created a degree of confusion over the detailed ORS concept itself, including how the government will seek responsive technologies, and the program's specific requirements, goals and milestones. To reduce the confusion, in 2008, the Department of Defense (DoD) released its *Implementation Plan for Operationally Responsive Space*. This plan communicates the responsive space capabilities the government intends to pursue using a prioritized "tier" program structure.[1] Regardless of any final ORS system architecture, space based platforms--and ultimately, warfighters--will benefit from timely and responsive transportation to operational orbits. This paper will examine current and future ORS spacelift options that are capable of supporting anticipated ORS requirements and the overall ORS effort.

[1] US Department of Defense, Implementation Plan for Operationally Responsive Space, Office of Deputy Secretary of Defense, 28 April 2008, 3-4.

The ORS program is confronting challenges that are concurrently analogous and dissimilar to those faced by General Bernard Schriever during the 1950s and 1960s in developing the nation's first Intercontinental Ballistic Missile (ICBM) capability. In basic terms, Schriever's task was to develop long-range missile weapon systems for the nation's new nuclear weapons technologies, while the ORS program's challenge is to provide space-based information age technologies and to make those capabilities available directly to operational forces within relevant timeframes. Like the early ICBM programs, ORS faces political indecision, conflicting services requirements, and the challenges of technology infusion and integration. While ICBM weapon systems were developed during a time of the highest US military peacetime spending in history[2], ORS programs will have to compete for funding with wartime spending obligations, economic stimulus programs, and service initiatives such as Army transformation and aircraft acquisition programs. Unlike Schriever's ICBM programs, which had to be created and matured, ORS will be able to leverage a highly developed and capable space industrial base that has already produced space systems capable of fulfilling the ORS program's requirements.

The purpose of this paper is to evaluate if the existing family of Evolved Expendable Launch Vehicles are capable of satisfying ORS responsiveness requirements. The paper will demonstrate that with properly targeted investments, and Concept of Operations (CONOP) changes, EELVs can meet most anticipated space launch responsiveness requirements. Additionally, this paper will identify the launch

[2] Jeffery F. Bell, "Bernard Schriever's Stifling Shadow," *Space Daily Your Portal to Space*, 28 September 2004, http://www.spacedaily.com/news/oped-04zd.html.

responsiveness requirements EELVs are incapable of satisfying and it will evaluate launch vehicle alternatives to address those specific shortfalls. Finally, this paper will examine spacelift systems in responsiveness terms as applied to general ORS concepts. The paper will not attempt to match specific ORS payloads or satellites to a particular launch vehicle or launch system.

Chapter 1 will "unpack" the ORS concept, past and present. Next, Chapter 2 will examine the drivers and needs for responsive space systems, that is, "Why ORS?" Chapter 2 will also capture and evaluate the ORS responsive launch requirements. Chapter 3 is dedicated to analyzing EELV's responsive launch capabilities and the currently untapped capacity not exercised by the current launch on schedule CONOP employed by government launch agencies. Additionally, Chapter 3 will discuss the investments necessary to unlock the responsiveness potential of the EELV system. Finally, it will also evaluate various EELV CONOPS that are available to improve system responsiveness. Chapter 4 will assess the Launch-on-Demand (LOD) concept and will analyze the launch vehicles capable of satisfying LOD requirements. Finally, Chapter 4 will evaluate if LOD is a necessary concept given the current and anticipated national security threat environment with regard to space. All told, this paper presents an alternate strategy for the ORS program to consider for ORS launch vehicle requirements.

ORS APPROACH

ORS Past

> Desert Storm was a watershed event for space systems. Satellites, and the ground systems and people trained to control them, played a crucial role in the outcome of the conflict. Space owned the battlefield. We had a robust on-orbit constellation and the inherent spacecraft flexibility to alter our operations to support specific needs of the terrestrial warfighter.[3]
>
> Lieutenant General Thomas S. Moorman

Space-focused after action reviews (AARs) and professional studies immediately following the first Gulf War praised space systems for their contributions to combat operations. However, not all conclusions and AAR findings were as positive as General Moorman's assessment; others contradicted his observations. For example: several studies concluded commanders needed additional space capability; combat operations competed with national priorities for limited sensor availability; redeploying space assets to support the theater of operations was extremely difficult or impossible; and, augmentation to operational space systems would take several months or years.[4] The term "responsive space" was coined to bundle these warfighting needs into a coherent concept that addressed these operational deficiencies.

---

[3] Lieutenant General Thomas S. Moorman, Jr., Presentation to General E.P. Rawlings Chapter, Air Force Association, Minneapolis, Minnesota, "*Space…The Future is Now*," 17 October 1991.

[4] John Diedrich. "*Military Learns from Gulf War Glitches, Updates Space Technology*," *Colorado Springs Gazette*, 27 January 2001. http://www.globalsecurity.org/org/news/2001/010127-space2.htm

The space launch community was the first to tackle the issue of operational responsiveness. The April 1994 Space Launch Modernization Plan, most commonly known as the Moorman Study, "establishes and clearly defines priorities, goals and milestones, regarding modernization of space launch capabilities for the Department of Defense or, if appropriate for the Government as a whole."[5] The study concluded the 1994-era fleet of launch vehicles had significant limitations in terms of cost, operability, and responsiveness.[6] In an attempt to address these limitations, Air Force Space Command (AFSPC) entered the process to acquire new expendable launch vehicles, and this acquisition eventually became the EELV program. EELV's responsiveness capabilities and role in future systems will be evaluated in Chapter 3, but it is important to introduce here due to the program's role in leading AFSPC's "responsiveness" discussions and debates.

The Operationally Responsive Spacelift (emphasis added--the "first" ORS) initiative was the operational space community's initial attempt to consolidate the responsiveness issues identified at the conclusion of the first Gulf War. *The Mission Needs Statement (MNS) for Operationally Responsive Spacelift* (Dec 2001) identified four key capabilities:[7]

1. On-demand satellite deployment to augment and quickly replenish constellations.
2. Launch to sustain required constellations for peacetime operations.

---

[5] US Department of Defense, Space Launch Modernization Plan, (Moorman Study), April 1994.
[6] Ibid., 26.
[7] Air Force Space Command (AFSPC) 001-01, Mission Needs Statement for Operationally Responsive Spacelift, 20 December 2001, 2.

3. Recoverable, rapid-response transport to, through and from space.
4. Integrated space operations mission planning to provide near real-time planning to enable on-demand execution of space operations.

A critical review of the MNS reveals "this concept lends itself to incorporation into a modular family of vehicles, thus permitting 1) support of a range of payload mass insertion needs, 2) flight rate and fleet size tailoring for an optimal balance between responsiveness, affordability, and survivability, and 3) cost-efficient utilization of the industrial base."[8] The key statement in the MNS and one that eventually led to restructuring the Operationally Responsive Spacelift concept into the Operationally Responsive Space program was "It is recognized that responsive payloads must be developed concurrently with ORS [Operationally Responsive Spacelift] to provide maximum benefit to the warfighter."[9] This "if you build it they will come" launch approach, divorced from similar payload capabilities, led to the Operationally Responsive Spacelift program's demise. However, the original ORS thinking, while limited to space lift, was valid and addressed many of the post Gulf War AARs space responsiveness issues identified almost a decade earlier. Over time, the key responsiveness tenants from the MNS were incorporated into a new (17 April 2007) Operationally Responsive Space plan.

[8] Globalsecurity, "Operationally Responsive Spacelift Initiative," http://www.globalsecurity.org/space/systems/ors.htm
[9] Air Force Space Command (AFSPC) 001-01, Mission Needs Statement for Operationally Responsive Spacelift, 20 December 2001, 2.

ORS Present

In April 2007, the Department of Defense (DoD) submitted to Congress its *Plan for Operationally Responsive Space*. Congress approved the plan, and at this time the ORS concept enjoyed the support required to actively pursue operationally responsive space capabilities. Unlike past plans focused on one system or capability, today's ORS plan includes the full spectrum of systems and capabilities to meet the combatant commanders' responsive space requirements.

> The Commander, United States Strategic Command (CDRUSSTRATCOM) has expressed three desires: first, to rapidly exploit and infuse space technological or operational innovations; second, to rapidly adapt or augment existing space capabilities when needed to expand operational capability; and third, to rapidly reconstitute or replenish critical space capabilities to preserve operational capability. These desires have led to a multi-dimensional concept to implement ORS to improve the responsiveness of existing space capabilities (e.g., space segment, launch segment, ground segment) and to develop complementary, more affordable, small satellite/launch vehicle combinations and associated ground systems that can be deployed in operationally relevant timeframes.[10]

In April 2008, DoD published a more detailed document, the *Implementation Plan for Operationally Responsive Space*. This plan identified a specific program office to pursue promising concepts and established the rules of engagement for acquiring new capabilities. The plan placed STRATCOM's desires into a three tiered structure designed to satisfy ORS's requirements. This tiered system is designed to guide and focus the space community's selection of promising technologies for further testing and

[10] US Department of Defense, *Plan for Operationally Responsive Space*, A Report to Congressional Defense Committees, 17 April 2007, 3.

development based on combatant commanders' requirements and responsiveness needs.[11]

The overall strength of the April 2008 plan is the specific strategic vision delivered to the space community and a concurrent authority to pursue solutions to responsive space needs. In addition, the tiered approach provided a beneficial structure to the space community's diffused efforts towards investigating many potential and emerging responsive space options. However, when the requirements as stated in the 2007 plan are combined with the directions for proceeding in the 2008 plan the weaknesses are glaring and problematic. First, specific solutions for meeting combatant requirements are given "The focus of Tier 2 solutions is….a small, low cost satellite."[12] By dictating a single solution, the program has limited the solution set to an option that may not meet the launch responsiveness requirements or on orbit capabilities the combatant commanders require. The second weakness is the "low-cost" portion of the solution statement. Cost constraints placed on programs attempting to develop and integrate leading edge technologies hinder innovation and are rarely successful. While current launch vehicles are expensive--ranging from the tens to hundreds of millions of dollars, when a new launch system's additive costs are considered (development, test, fielding and the industrial base), purchasing a small number of extra EELV boosters for anticipated or actual responsive launches can make it an economic bargain. This point will be argued more strongly in Chapters 3 and 4.

---

[11] US Department of Defense, *Implementation Plan for Operationally Responsive Space*, 28April 2008.

[12] US Department of Defense, *Plan for Operationally Responsive Space*, A Report to Congressional Defense Committees, 17 April 2007, 3.

WHY RESPONSIVE SPACE

Arguments Defined

Since Desert Storm, integrating existing space capabilities and delivering emerging space technologies directly to the warfighter has become an important focus of the military space community. Today, our operational forces rely on space capabilities for situational awareness; intelligence, surveillance, and reconnaissance (ISR); wideband and secure communications; positioning, navigation, and timing (PNT); missile warning; weather; and, more. Many of these space-provided capabilities were not available, extremely limited, or could not be delivered in a timely manner to the warfighter during Desert Storm. “One need only compare Desert Storm with Operation Enduring Freedom or Operation Iraqi Freedom to see how successful we have been at operationalizing our global space forces. One of the key differences between Desert Storm and Operation Iraqi Freedom is the distribution of satellite-based wideband communications down to the tactical level.”[13]

Today, the U.S. armed forces are by far the strongest and most capable military force on earth, and our space forces are without peer. Considering the current advantages in-place space assets provide our forces, and the use of Unmanned Ariel Vehicles on the battlefield to augment some space capabilities, one may legitimately ask if we need ORS. This is an emotionally charged question that surrounds the ORS

[13] US Senate, *Arthur K. Cebrowski: Director of Force Transformation Office of the Secretary of Defense, Before the Subcommittee on Strategic Forces,* 25 March 2004, 4.

program; the answer is a complex web of issues driven by the National Security Strategy (NSS). Additionally, in light of the nation's current economic problems and DoD budget shortfalls, even if the answer is "Yes, we need ORS," a follow-on question emerges, "Do we need it now?"

The short answer appears to be 'yes.' The issues ORS purports to solve should be addressed sooner rather than later, largely because of the transformation effects that space has provided to air, ground, and maritime forces. The value of these effects will not diminish, so recognizing that "the nation's space capabilities directly impact speed of maneuver, the tempo of the fight, and the boldness and lethality of our forces,"[14] it's appropriate to conclude the warfighter requires worldwide, timely, and assured on-orbit capabilities. Therefore, "the ability to maintain, replenish, and augment space assets in a given theater is now more operationally and time critical than ever."[15]

The "augment and reconstitute" argument appears to support the original Operationally Responsive Spacelift approach. As pointed out in Chapter 1, spacelift alone will not provide the responsive capability without satellites, infrastructure, and user equipment ready for rapid deployment. The ORS plan recognizes the importance of responsive launch vehicles and states "Initial ORS efforts will focus on providing rapid launch capabilities (launch vehicles, launch infrastructure, and associated launch support)…"[16] Fortunately, the Air Force already operates spacelift systems that are capable of meeting most responsiveness requirements. By utilizing existing launch

---

[14] US Senate, Arthur *K. Cebrowski: Director of Force Transformation Office of the Secretary of Defense, Before the Subcommittee on Strategic Forces,* 25 March 2004, 4.
[15] Air Force Space Command, *AFSPC Position Paper on Assured Access to Space*, 2004, 1.
[16] US Department of Defense, *Plan for Operationally Responsive Space,* A Report to Congressional Defense Committees, 17 April 2007, 5

systems, the ORS program can concentrate fulfilling other aspects of responsive space that will meet the combatant commanders' requirements.

Responsiveness Defined

The next chapter will analyze the responsive systems mentioned above. In order to discuss the launch systems in detail, the term "responsiveness" must be defined. The words "responsive," "rapid," and "quick" all are mentioned in the April 2008 ORS implementation plan in regard to spacelift requirements, however, these descriptors are imprecisely defined using the terms days, weeks and months in the ORS plan's tier structure. Additionally, the tier structure outlines requirements to deploy entire space systems and does not contain responsive launch requirements. However, with a careful examination of the tier structure and the deployment timelines contained in each tier, responsive launch requirements can be estimated. The three tiers and their associated timelines are defined as follows:

- Tier 1: On-demand use of existing systems. Tier 1 does not require responsive launch capabilities and is the existing model for launch.
- Tier 2: Deploying new or additional capabilities that are "field ready." The objective of tier 2 is to deliver capabilities in days to weeks. This requirement is the baseline for the EELV responsiveness argument.
- Tier 3: The rapid development, delivery, and employment of a new capability. The objective is to deliver a new capability in less than one year. This could be an EELV capability (or some other launch vehicle) depending on the requirement of the new system. Tier 3 could possibility

be a Launch on Demand (LoD) capability mentioned in other plans and publications.[17]

[17] US Department of Defense, *Implementation Plan for Operationally Responsive Space*, 28April 2008, 3-4.

EELVs FOR ORS

EELV Description

While it is unlikely that EELV will now attract the large number of commercial payloads that were initially expected,[18] it was designed and engineered to support a robust launch schedule. This means the EELV has an associated launch infrastructure that can still accommodate a significant launch demand. Currently, United States Government (USG) launch agencies use a "launch on schedule" Concept of Operations (CONOP) that does not require the EELV system to be meet launch rates the ORS program would consider "responsive." However, with targeted additional investments and changes to the CONOP, the EELV family of launch vehicles could meet most ORS Tier 2 and 3 responsiveness requirements. In 2006 the Office of the Secretary of Defense (OSD) commissioned RAND to study U.S. launch vehicles and publish the *National Security Space (NSS) Launch Report*. The study concluded, "Ample evidence suggests that these rockets (EELVs) can meet the NSS launch needs of the United States through 2020 (the end of the study period), barring the emergence of payload requirements that exceed their design lift capability."[19] In addition to EELV, the U.S. has access to a variety of smaller launch vehicles that are either currently operational or are in development. These vehicles also have the potential to meet ORS responsiveness requirements.

[18] Article Archives, "Can EELV meet US National Security Launch Needs?" Interavia Business & Technology, 22 September 2006. http://www.articlearchives.com/science-technology/astronomy-space-spacecraft/752386-1.html
[19] RAND, *National Security Space Launch Report*. Santa Monica, RAND Corporation, 2006, xvi.

The Congressionally mandated National Security Space Launch Report, produced by RAND in 2006 provides the following background on the EELV program. In August 1994, in recognition of the vital role played by space transportation systems, the Clinton administration issued *National Science and Technology Council–4*, commonly known as the 1994 NSTP. The directive stated that assuring reliable and affordable access to space was a fundamental goal of the U.S. space program.[20] To this end, the policy mandated that appropriate government agencies work to maintain strong launch systems and infrastructure while modernizing space transportation capabilities and encouraging cost reductions. In October 1994, the U.S. Air Force was selected as the executive agency for the newly created EELV program.[21]

> The objective of the project was to develop a national space launch system capable of reliably satisfying the government's national mission model requirements while reducing space launch costs by at least 25 percent. Under the EELV program's original [1994] acquisition strategy, the Air Force would select a single contractor. In November 1997, however, a new acquisition approach was adopted because it was determined that a larger than previously envisioned commercial market would support two contractors. The intent was that this new arrangement would create two vehicle families capable of meeting government requirements while also capturing commercial launches, which would result in lower mission costs and higher reliability for all. Currently, the EELV program consists of two families of launch vehicles as well as associated launch infrastructure and support systems. Lockheed Martin's Atlas V family is built around a Common Core Booster powered by the Russian-built RD-180 engine; it began operations in August 2002 and has completed eight successful flights with no failures. Boeing's Delta IV family is built around a Common Booster Core powered by the Pratt & Whitney Rocketdyne RS-68 engine; it began operations in November 2002 and has completed six successful launches.[22]

Together, the additional contractor and the reduced commercial market demands have created excess capacity which could be used by the separate EELV vehicle families to fulfill ORS Tier 2 responsive requirements. The launch vehicle families are shown in Figure 1.

[20] RAND, *National Security Space Launch Report*. Santa Monica, RAND Corporation, 2006, xvi.
[21] Ibid., xvi.
[22] Ibid., xiv-xv.

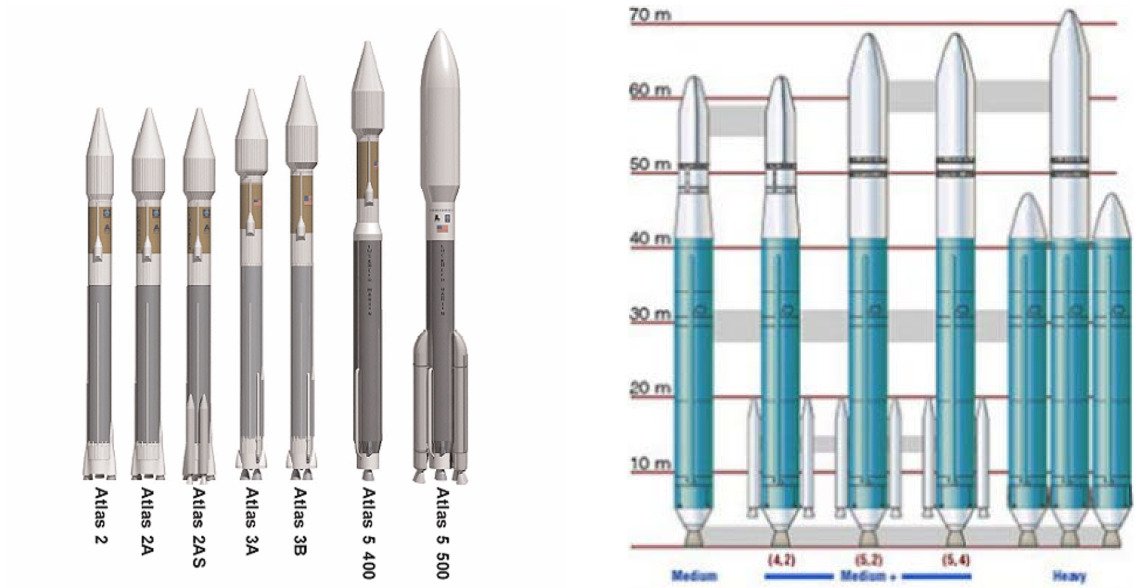

Figure 1: Lockheed Atlas V[23] and Boeing Delta IV[24]

Responsive EELVs

Responsive launch requirements for the EELV system have been established by AFSPC's Operational Requirements Documents (ORD). AFSPC published two ORDs for the EELV launch vehicle system, *ORD-1*, 22 Oct 96 and *ORD-2*, 15 Sep 98. *ORD-1* was produced when the acquisition strategy was to select one launch provider; *ORD-2* was created to reflect the changed acquisition strategy that would retain two contractors and better leverage the anticipated commercial launch market. The total launch rate of 26 per year contained in *ORD-1* was reduced, to 18 per year in *ORD-2.* However,

[23] Wikmedia Commons, "Atlas EELV Family.png." http://commons.wikimedia.org/wiki/Image:Atlas_EELV_family.png
[24] GlobalSecurity, *Delta IV EELV-McDonnell Douglas*, http://www.globalsecurity.org/space/systems/eelv_m.htm

because *ORD-2* called for both contractors to meet the new 18 per year launch rate, it created a requirement for a total increase of up to 10 additional launches per year.

ORD-2 defines launch rate requirements in terms of responsiveness (Call-Up), Launch Rate (Basic), resiliency (Maximum Sustainable Launch Rate), and Crisis Response (Surge or Peak Capacity). The term "Crisis Response" would correspond to the ORS program's most responsive launch requirement and is defined as "an increase in launch rates above the maximum sustainable rate to provide on-orbit support to the warfighter.[25] This capacity would be above the maximum sustainable rate. It will allow previously unscheduled payloads to be entered into the launch schedule with a minimal effect on previously planned payloads. The objective was to launch up to three unscheduled medium payloads (two East Coast and one West Coast) within a 2-month period every 12 months.[26] Combined with the basic launch rates of 12 launches at Cape Canaveral Air Station (CCAS) per year, which may include one heavy mission, and six launches at Vandenberg Air Force Base (VAFB) per year, with two contractors, the total launch capability would be 48 launches per year, or 4 per month. Because of cost trade-offs while acquiring the EELV system, strategy changes, and realities of the commercial market collapse, the *ORD-2's* required launch rates were never realized by the EELV system; Delta IV and Atlas V have a to-date combined total of 24 launches over the last 6 years. None-the-less, the EELV system was designed to satisfy a high launch rate, and the associated EELV launch infrastructure was built to meet the *ORD-2* requirements. Accordingly, today's EELV launch system is underutilized and an

[25] Air Force Space Command, (AFSPC 003-93-I I) *Operational Requirements Document (ORD) II For The Evolved Expendable Launch Vehicle (EELV) System*, 15 September 1998, 11.
[26] Ibid., 11.

opportunity exists for ORS to exploit EELV's unlocked responsive capabilities at what would be expected to be relatively low cost.

Program and CONOPS

The last section made clear the EELV infrastructure is in place to support ORS requirements. However, the current acquisition program and CONOPS would require changes to accommodate and support ORS responsiveness requirements. Keep in mind while reading this section that program and CONOPS changes would require investment from the United States Government. This is important to note when discussing the trade-offs between using existing systems and acquiring a new family of launch vehicles for the ORS program.

In order to meet the ORS responsive launch requirements, a launch vehicle would have to be physically available at the launch base for crisis response call-up. Currently, the EELV program office purchases boosters based on an approved planning document called the *National Launch Forecast* (NLF).[27] Based on the NLF, the contractor is notified or awarded a mission nearly two years in advance and the booster is called-up (ordered) one year prior to the required launch date. At that time, the launch vehicle is assigned to support a particular space mission. Air Force, National Aeronautics and Space Administration (NASA), and the National Reconnaissance Office/Office of Space Launch (NRO/OSL) all assign mission assurance teams to track "their" booster from production, to the launch base, and through launch operations. They also monitor the changes needed for the booster to accommodate a specific spacecraft. In the current system, a booster is not available for use by anyone else,

[27] Dr. Walter Lauderdale (Atlas Program Deputy, SMC/LRSV), interview by author, 24 November 2008.

including ORS, other than the specific customer; that is, a booster and a spacecraft become a "matched pair."

To address the assured access requirements in the ORD, AFSPC had at one time proposed a "rolling booster" CONOP. This CONOP called for an already manufactured booster to be present at the launch base for an instant call-up.

> The rolling booster concept allows the USG to order a generic LV (launch vehicle) early and use it as an available inventory item in case of a rapid launch need. This generic hardware configuration will reflect the USG's expectation of mission needs to ensure that all required hardware items (booster, upperstage, fairing, strap-ons) are available when needed. The rolling booster aspect means that hardware is used for the next manifested mission, therefore, not subject to component life and obsolescence issues. In a nutshell, this approach provides the USG the use of the next available booster.[28]

At the time of the rolling booster proposal, AFSPC envisioned a robust launch schedule that failed to materialize, resulting in the current launch on schedule CONOP. The rolling booster concept has a weakness in that the USAF, NASA, the NRO, and a variety of contractors might have to make internal mission assurance CONOP adjustments and address schedule changes to accommodate the "rolling booster" or crisis launch with little or no benefit to their programs. However, the influx of funding provided by an additional customer into the EELV program would result in reduced "overhead" (shared) costs and would create a responsive EELV capability that could eventually benefit all launch customers.

Small Payload Adapter

Another capability that should be of interest to the ORS program is the EELV Secondary Payload Adapter (ESPA; see Figure 2). "The ESPA is designed to take

[28] Air Force Space Command, *AFSPC Position Paper on Assured Access to Space*, 2004, 5.

advantage of unused payload margin to deploy up to six 181 kg (400 lb) secondary payloads. ESPA consists of an aluminum cylinder with six standardized secondary payload (SPL) mounting locations. The fore and aft flanges on the ESPA ring duplicate the 157.5 cm (62.01 in) EELV Standard Interface Plane, making ESPA transparent to the primary payload. By taking advantage of existing unused payload margin, ESPA will increase access to space for small satellites and space experiments."[29]

The ESPA was successfully employed on the Space Test Program (STP)-1 mission in March 2007 on an Atlas V vehicle from Cape Canaveral Air Station and deployed six satellites in two separate low earth orbits.[30] The STP-1 launch demonstrated that a set of interrelated satellites could be successfully deployed to at least two orbits. Additionally, the set of satellites shared the cost of the launch, thereby significantly lowering the total cost to each individual satellite program. This was ESPA's only launch to date. Unfortunately, many primary satellite programs consider using the ESPA with "their" launch as additional risk and discourage or refuse to offer the additional margin to others. This "launch margin ownership" issue needs to be changed with policy from the Secretary of Defense.

The ESPA, by itself, is another option to consider verses developing a small launch vehicle for small payloads. The ESPA provides the opportunity to package or bundle small satellites with a larger payload to provide a package of capabilities to the combatant commander. Coupled with the rolling booster CONOP, this capability can

---

[29] P M Wegner, J. Ganley, JR Maly, *EELV Secondary Payload Adapter (ESPA): Providing Increased Access to Space*, Air Force Research Lab Space Vehicles Directorate, Kirtland AFB NM, 2001, Abstract. ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=931218

[30] Cary D. Pao, (Aerospace Corp Engineer SMC/LRSV), interview by arthor, 24 November 2008.

not only meet responsive launch needs but also provide a robust, tailorable, and scalable set of on-orbit missions for a specific theater or combat operation.

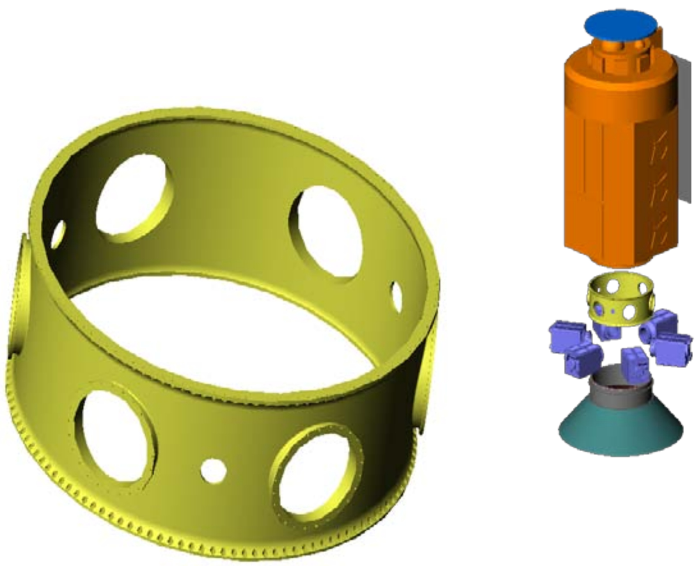

Figure 2: ESPA Payload Adapter Concept[31]

LAUNCH ON DEMAND

The "crisis launch" need for launch-on-demand (LOD) has long been associated with the ORS concept. In fact, the American Institute of Aeronautics and Astronautics yearly Responsive Space conference featured eight separate LOD presentations and

[31] Mr Cary D. Pao, Lt Ray Kim, *EELV Secondary Payload Adapter (ESPA) Standard Launch Service*, Presentation at NRO/AIAA Space Launch Integration Forum, 16 July 2008.

papers in the last four years.[32] However, the ORS implementation plan does not mention LOD as either an initiative or requirement for the ORS program. Instead the plan, requires "ORS to improve responsiveness of existing space capabilities and to develop complementary, more affordable, small satellite/launch vehicle combinations and associated ground systems that can be deployed in operationally relevant timeframes."[33] It is unclear what caused the omission of LOD concept from the ORS implementation plan, but perhaps LOD advocates are attempting to avoid many of the same questions and stigmas that led to the demise of the original Operationally Responsive Spacelift concept. The ORS implementation plan does include some less controversial wording implying LOD, but instead emphasizes the imprecise phrase "operationally relevant timeframes."

Launch-on-Demand is a launch concept which envisions space capabilities being deployed within hours or a few days of call-up. Current launch vehicles, including EELVs are not capable of meeting these call-up requirements. To acquire this capability the USG would have to pursue new launch vehicles, infrastructure, and command and control capabilities. "The key requirement is that the launch vehicle be essentially a commodity, built to inventory, and ready to go whenever needed, much like cruise missiles or rental cars"[34] Some in the industry are looking to the future and beginning to develop capable new systems that may eventually meet LOD requirements. New promising systems include: FALCON, Minotaur, Scorpus, Air Launch and a handful of others. However, some in the spacelift industry question the

---

[32] Responsive Space Website, http://www.responsivespace.com/index.asp

[33] US Department of Defense, *Plan for Operationally Responsive Space*, A Report to Congressional Defense Committees, 17 April 2007, 3.

[34] Thomas P. Bauer et al., *Systems Engineering for Responsive Launch*, Microcosm, Inc., El Segundo CA, 2006, 1.

military utility of launch-on-demand systems and whether the threat environment actually exists to support development efforts. Lou Amorosi, vice president of Orbital Sciences Corporation questions the importance of ORS's responsive launch (that is, LOD) requirements. He points out that the Pegasus and Taurus launch vehicles are both capable of high launch rates, with surge rates of one per week, yet no one has used this responsive option in the 18 years the capability has been available.[35] Given its current direction, the ORS program is working to a 2015 initial capability date for small launch vehicles that can meet the aforementioned "operationally relevant timeframes."

As described above, EELVs cannot meet LOD timeframes for launch. However, the concept offered in the previous chapter, where EELVs and ESPA are used to deploy a set of capabilities to the combatant commanders, has essential elements that are shared with some LOD ideas and potential CONOPs. "The key to configuring a practical LOD system is defining a small set of "core" bus vehicles that can "mix and match" with a number of payload "kits" to satisfy the specific needs of the mission."[36]

Given that the ideas are similar, the only departure between the EELV CONOP offered in the previous chapter and the LOD concepts are the actual timeframes from launch call-up to launch. This takes the argument back to "operationally responsive timeframes," the threat environment to the nation, and the combatant commanders' needs.

---

[35] Jeff Foust, *"Operationally Responsive Space: A Solution Seeking a Problem"*, The Space Review, 13 October 2003, 2. http://www.thespacereview.com/article/52/1

[36] Jeff Summers, Greg Heinsohn and Greg Hegemann, "LAUNCH-ON-DEMAND; A Revolutionary Paradigm for Space Utilization", MicroSat Systems, Littleton CO, 2003, 5.

CONCLUSION

Today's military depends on space capabilities for effective and efficient combat operations. Since the first Gulf War, much progress has been made integrating on-orbit space capabilities into traditional operational and tactical combat operations. The ORS program's task is to develop new space systems that will meet combatant commanders' requirements and deploy these capabilities in operationally relevant timeframes.

One option available to meet ORS responsive launch requirements is the EELV family of launch vehicles. Changes in launch operations CONOPs and use of the ESPA provide the flexibility and responsiveness needed to meet combatant commanders' requirements. While actual costs were not studied, investments necessary to ensure vehicles and infrastructure are ready for crisis launches are likely substantial. However, when compared to developing, testing, deploying, operating and maintaining an "exclusive use" launch system, this EELV option appears quite sensible.

Now is an opportune time to take advantage of EELVs responsiveness capabilities. The EELV program office is continually "right sizing" the EELV workforce and infrastructure to meet the demands of launch on schedule requirements while providing a lower cost launch capability to USG satellite programs. This program optimization includes making cost trades and consolidation initiatives that affect responsiveness capabilities. These "initiatives" are still reversible, but the window of opportunity will not last forever. The addition of ORS as a USG user would enhance the EELV system for all users.

Beyond the Intercontinental Ballistic Missile (ICBM) there is still no validated requirement for launch-on-demand systems. However, the ORS office needs to monitor and encourage the technological developments required for a future LOD capability.

RECOMMENDATIONS

Based on the preceding analyses and conclusions, ORS should pursue EELV launch system capabilities to meet their responsive launch requirements. To ensure EELV capability is available when needed, the following recommendations are made:

1. DoD expand ORS Tier 1 objectives to include existing launch systems.
2. The USG abandon development of Launch-on-Demand systems until requirements are validated.
3. DoD precisely define responsive launch requirements in terms of time.
4. Air Force Space Command revalidate the EELV ORD-2 responsiveness requirements.
5. The ORS Program Office pursue the rolling booster and ESPA concepts/capabilities with the EELV Program Office.
6. The Secretary of Defense publish policy on the use of payload margin for USG satellite programs. The policy needs to direct the maximum use of launch vehicle margins practical, and would require mission agencies to obtain the Secretary's waiver if they feel maximal use of payload margin is impractical.

These recommendations provide a baseline for moving the conversion from the ORS program's small expendable vehicle focus to an EELV based focus. The EELV concepts described can meet launch responsiveness requirements and provide long-term program cost savings.

BIBLIOGRAPHY

Air Force Space Command Document (AFSPC 001-01). *Mission Needs Statement for Operationally Responsive Spacelift*, 20 December 2001.

Air Force Space Command Document *AFSPC Position Paper on Assured Access to Space.* Colorado Springs, CO: 2004

Air Force Space Command Document (AFSPC 002-93-I Rev-1). *Operational Requirements Document (ORD) I (Rev 1) For The Evolved Expendable Launch Vehicle (EELV) System*, 22 October 1996.

Air Force Space Command Document (AFSPC 003-93-I I). *Operational Requirements Document (ORD) II For The Evolved Expendable Launch Vehicle (EELV) System*, 15 September 1998.

Article Archives. "Can EELV meet US National Security Launch Needs?" Interavia Business & Technology, 22 September 2006. Accessed at http://www.articlearchives.com/science-technology/astronomy-space-spacecraft/752386-1.html

Bauer, Thomas P., Shyama Chakriborty, Robert Conger and James R. Wertz (Microcosm, Inc). *"Systems Engineering for Responsive Launch"*. Presented at AIAA 4th Responsive Space Conference, Los Angeles, CA. 24 April 2006.

Bell, Jeffery F. "Bernard Schriever's Stifling Shadow". *Space Daily Your Portal to Space*, 28 September 2004. http://www.spacedaily.com/news/oped-04zd.html

Diedrich, John. *Military Learns from Gulf War Glitches, Updates Space Technology*, Colorado Springs Gazette, Colorado Springs CO, 27 January 2001. Accessed At http://www.globalsecurity.org/org/news/2001/010127-space2.htm

Foust, Jeff. *"Operationally Responsive Space: A Solution Seeking a Problem"*. The Space Review, 13 October 2003. http://www.thespacereview.com/article/52/1 (accessed 14 December 2008)

Globalsecurity.org (n.d.) *Operationally Responsive Spacelift Initiative*, Retrieved Oct 31, 2008 from Globalsecurity.org: http://www.globalsecurity.org/space/systems/ors.htm

GlobalSecurity.org. *Delta IV EELV-McDonnell Douglas*. http://www.globalsecurity.org/space/systems/eelv_m.htm (accessed 7 December 2008).

Lauderdale, D.W. *Interview with Atlas Program Deputy by Lt Col Steele*, Air Force Space and Missile Center, Los Angeles CA, 24 Nov 2008.

Longquest, John Clayton. The Faces of Atlas: General Bernard Schriever and the Development of the Atlas ICBM 1953-1960. Ann Arbor, MI: Proquest, 2006.

Moorman, Lt Gen Thomas S. USAF, Commander Air Force Space Command, *Space…The Future is Now*. Addresses the General E. P. Rawlings Air Force Association Chapter, Minneapolis MN, 17 October 1991.

Pao, Cary D. EELV *Secondary Payload Adapter (ESPA) Standard Launch Service*. Briefing Presentation to NRO/AIAA Space Launch Integration Form, 16 July 2008.

Pao, Cary D. *Interview with Aerospace Corporation Engineer by Lt Col Steele,* Air Force Space and Missile Center, Los Angeles CA, 24 Nov 2008.

RAND Corporation. *National Security Space Launch Report*. Santa Monica, RAND Corporation, 2006.

Responsive Space Website. http://www.responsivespace.com/index.asp (accessed 18 November 2008).

Sega, Ronald M. Dr. "DoD Stands Up Joint Space Office (Sega Speech)". Air Force Link, 22 May 2007. http://www.af.mil/news/story.asp?id=123054214 (accessed 18 January 2009). US Department of Defense. *Space Launch Modernization Plan (Moorman Study)*,Washington D.C.: Office of Deputy Secretary of Defense, 6 May 1994.

Summers, Jeff, Greg Heinsohn and Greg Hedgemann (Microsat Systems). *"LAUNCH ON DEMAND, A Revolutionary Paradigm for Space Utilization"*. Presented at AIAA 1st Responsive Space Conference, Redondo Beach, CA. 1 April 2003

US Department of Defense. *Implementation Plan for Operationally Responsive Space,* Washington D.C.: Office of Deputy Secretary of Defense, 28 April 2008.

US Department of Defense. *Plan for Operationally Responsive Space: A Report to Congressional Defense Committees*, Washington D.C.: Office of DoD Executive Agent for Space and Commander US Strategic Command, 17 April 2007.

US Department of Defense. *Space Launch Modernization Plan*, Washington D.C.: Office of Deputy Secretary of Defense, 5 May 1994.

US Senate. *Arthur K. Cebrowski: Director of Force Transformation Office of the Secretary of Defense, Before the Subcommittee on Strategic Forces,* United States Senate Armed Services Committee, 25 March 2004.

Wegner P. M., J. Ganley, JR Maly, *EELV Secondary Payload Adapter (ESPA): Providing Increased Access to Space*, Air Force Research Lab Space Vehicles Directorate, Kirtland AFB NM, 2001, ieeexplore.ieee.org/xpl/freeabs_all.jsp?arnumber=931218

Wikmedia Commons. "Atlas EELV Family.png." http://commons.wikimedia.org/wiki/Image:Atlas_EELV_family.png (accessed 7 December 2008).